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Managing the Economy of Public Mosquito Control Thresholds

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Abstract

Seventy-four mosquito surveillance data sets involving over 35 species, from January 2013 to December of 2014 have been obtained with permission from Dr. Carl Boohene and Polk County Mosquito Control District in Central Florida and used as data for this project. These data are utilized to propose a practical, economically-based decision rule model that uniquely integrates human populations with mosquito species populations and budgetary constraints. Two different decision rule conventions are proposed and the choice to go with one of them reflects differing economic expenditure inroads on budgeted chemical and equipment resources. In general, if the threshold is higher, then resource consumption is relatively low; and if lower, then resource consumption is higher. The application of special thresholds, (specifically when mosquito-borne disease infection rates in humans and/or mosquitoes are determined to be higher, or via age grading by ovary dissection and surveys of gravid mosquitoes) are discussed. Aspects of mosquito biology, and surveillance information, as well as the benefits and limitations of proposed action thresholds and other applicable mosquito control information are also discussed. Data sheets in Excel book form, application rates and pesticide are included.

Dynamic Biological and Environmental Variability Require Corresponding Solutions

These data contain over 35 pestiferous mosquitoes and other species of public health importance from Polk County. The variable dynamics of mosquitoes and the arrangement and management of their activities require answers that are equally dynamic, as well as economically practical. The word “Economic” (Greek-oikonomikos), which this writer uses will be defined as *the management and arrangement of activities* as also the Greek word suggests. Once prescribed dynamic thresholds are reached they must be inseparably integrated with available resources, and human population levels in dynamic mathematical form. The action thresholds, and which are uniquely determined for each of the 73 surveillance periods in our project will be discussed, as well as their implications. The writer will discuss the reasons for and types of action thresholds used; the methods and equipment used in this project; the arbitrary use of mosquito control action thresholds vs this model; the implications and nuances of a dynamic action threshold design and some conclusions that can be drawn for practical use in public mosquito control strategies as well as private venues.

Why we Need Surveillance Models and Treat or No Treat Decision Rules

The reasons for decision rules or what we may refer to as actionable thresholds are numerous. Among them are legal requirements (NPDES, state regulations, etc.); evaluation of results and practical effectiveness; pesticide preservation and the prevention of insect resistance as a condition resulting from misuse; for environmental responsibility and safety as well as the need for knowledge derived from scientifically based methodology and observation.

Numerous Types of Action Thresholds but All Have Economic Impacts

According to Koehler, Kern and Pereira, the list includes health and safety, legal thresholds, pest acceptance thresholds and economic thresholds (page 19-20). The writer of this project sees all these as having economic impacts in their relative spheres, where health and loss of life, legal constraints; pest acceptance, and human comfort all impact monetary inroads in one way or another. One example of this occurred in Dallas Texas where economic loss resulting from a single Saint Luis Encephalitis outbreak occurred infecting 172 victims; and where projected losses were measured systematically from a holistic point of view, in which losses were measured across individual, societal and governmental economic scales and expressed by an economic loss of $795, 500.00 or $6,127,166.88 in today's money (Schwab, 1968). In a similar case, if one fast-forwards to the present, to a mosquito control agency in Dallas or other city, human morbidity, mortality and stress might well serve to warrant the prevention of these kinds of losses, since preventative measures (chemoprophylaxis or better yet: "Adulticide-prophylaxis") through *the management, and arrangement of activities* in this case would help prevent many losses.

What This Project Model Can and Cannot Do

Although the model is sound, it is important to specify some important exceptions and to provide both practical and scientific reasons for them. To begin with, the data are static. In other words, since mosquito adulticiding treatment missions cannot impact data sets (data sets are from 2013-2014) significant reductions in mosquito population levels resulting from the application of our methodology cannot be evaluated through this project. When we are live (real time), normal spray missions, if properly applied would result in significant reductions in the numbers of mosquitoes, as shown by empirical surveillance and trapping methodology and would impact collection numbers as well as observed species diversity in samples. Nevertheless, the purpose and scope of this paper are to promote a logistical method that prioritizes *the management and arrangement of treatment activities* (via the integration of human populations which are subject to mosquito-caused stress and infirmity with mosquito populations that subject them to these factors in the decision rule process) before control decisions are made. Statistical significance in methodology is valid if sample sizes are large enough; and on that point, larger is better. It would have been ideal if treatment areas, treatment methods as well as pre and post treatment data had been consistent and available over much longer periods. If in any given week with two trap nights per week for 30 years (I will go over methods and equipment in the next section), then for each of the 52 weeks of the year we would have 30 data sets to firmly establish decision rule effectiveness, so that we could either confirm or modify treatment and surveillance methodology. Because conditions and data usually are not ideal we must do our best, notwithstanding current empirical limitations.

Methods and Equipment

The method to be used will involve the use of human population data among 35 or more species derived from Polk County GPS and Polk County Mosquito Control. Each of the 43 treatment zones uses demographic information and population statistics initially received from The US Census Bureau and then processed by the Polk County GIS Department, who associated each of the geographical zones information with their constituent human populations (see documentation included with project submittal). Mosquito surveillance data and actual spray zone acres for each zone were contributed by Dr. Carl Boohene, PhD and cover a period of 2 years, from FY 2013 through 2014.

This mathematical convention is derived from a simple formula developed by the author and can be described as follows: Total number of humans in Zone A over Total of humans in all zones Z, expressed as (A/Z). Then we multiply the number of mosquitoes collected per trap night at each zone site. Thus, if zone 22 is calculated, then (22,885/478,397) x 1 mosquito collected has a priority value in the action threshold spectrum, which in this case is 0.048. By the same 4.28 token, if the human population from zone 7 were used (18576/478,397) x 1= 0.038, then we understand it is obviously lower than the first example and is of lower priority. In a very real sense this example would not normally warrant a control application if on a given trap night the highest threshold was 0.048! The example is merely presented here to explain how the model works. To better illustrate how it works: if we refer to data sheet 73 from December 14th, 2014, I have color coded prioritized tiers, based on the [(numbers of humans in a specific zone over the number of humans in all zones together) times the number of mosquitoes collected in a zone] during an individual trap night. Expressed mathematically, we have for example, zone 22 and trap number 9-42 (22885/478397) x 475 mosquitoes, thus giving us a tier priority of 23.2. If we go down further to tier 7 (blue color code) we have a threshold priority of 4.28 for Area 28- trap 125. On the 10th tier (pink) we have a threshold or tier priority of 2.97, the lowest of the top ten. The numbers of mosquitoes in each zone are shown in Column AK and the unprioritized tiers are in column AM. Prioritized tiers are shown in columns AQ-AS. Please refer to data sheets provided to get an idea of common, actionable thresholds. Each threshold is like a snow-flake; it is unique to a specific trap night! As mosquito tallies increase, so do potential thresholds for each individual trap night. We continue this reckoning for each trap night from zone 1 to 43, while tracking species collectively. Afterward, we sort each threshold potential from highest value to lowest, while keeping in mind that each factor includes both human and mosquito elements, rather than an oversimplification involving only mosquito tallies from a collection sample. While both public and private mosquito control agencies often take human populations into account, the decision to treat any zone frequently rests on arbitrary rules and applicators may take decisions to treat areas of lower priority first, with little impact or concern over human exposure or environmental conditions. It is important to note in lieu of treatment potential that action thresholds in and of themselves are independent of the number of ULV trucks and equipment available to carry out spray missions. Increased resources simply allow for lower thresholds to be acted upon. If a lower treatment threshold per data set (trap night) is desired, then we may correspondingly add more equipment and trucks to carry out missions. Generally, higher thresholds involve fewer equipment and vehicular resources and result in correspondingly fewer potential pesticide allocations (inventories), treatment acreages and pesticide usages.

Equipment and Chemical Used and Control Measure Options

In this economic decision rule model, we have a total of ten ULV (ultralow volume) spray trucks equipped with an 18 HP truck mounted fogger. Using thresholds derived from a lower action threshold we arrive at a 30% increase in spray missions, acreage, but a higher one where only 7 are used and results in a 30% decrease in pesticide consumption and total acreage. Sheet 74 in the workbook shows the difference. If 7 trucks are used, we have a total of 13, 755.2 gallons and 1,760, 681.11 acres over two years vs 2,488,564.94 acres and 19,441.91 gallons with 10 trucks and therefore, the choice to use lower thresholds require more resources. The data also references mean numbers for both conventional models.

The choice of adulticiding chemical to be used to carry out potential treatment missions is a permethrin-based formulation to be disbursed by ULV at an application rate of 1 ounce per acre. I have included the calibration data sheet and manufacturer's label as part of the project submitted for reference purposes.

The choice of mosquito surveillance traps will include CDC styled CO2 baited miniature light traps which are setup in 43 zones and will target at least 35 species of Culicidae (mosquitoes).

Which Threshold Model Should We Use if Arboviral Diseases are a Problem?

There are numerous methods by which we may adjust our economically-based (based on budgetary allotments of chemicals, spray equipment and available resources) action thresholds. It may be best to use a normal allocation of 7 vehicles, based upon desired acreage, and budgetary constraints under normal circumstances where there are no existential threats of mosquito-borne disease acquisition. A special decision rule will allow us to modify existing conventional structure by using lower action thresholds at 3 lower tiers (if we have 10 ULV trucks) when CDC or public health reports show a disease potential exists in a geographic area. Once we know a potential outbreak exists, then we can monitor gravid mosquitoes and their ratio in vector mosquito samples as compared to nulliparous specimens which pose little or no immediate threat to human populations (we still focus on areas with higher population, which is intrinsically built into our tier-based action threshold model). Long-lived gravid mosquitoes will exhibit ovarian degradation as represented empirically through ovarian dissection under microscopic examination. Another way would be to test mosquito pools of 50 or more and determine how high or low the infection rates may be in observed gravid samples. The larger the number of positive pools, the greater the potential of disease transmission to humans or bridge vector mosquito species and their hosts. Sentinel bird serology of chickens placed in strategic locations for the detection of West Nile or SLE may also be advantageous. The bottom line is that through whichever methods we may choose, we can choose lower action thresholds and target potential vector species in the areas that they are detected by adding a corresponding number of ULV trucks. The collection of data and species composition ensures us that we can at least target them, whether we test them or not.

Why Simple Trap Counts are a Big fail

Because simple trap counts that target species have built in design on the appropriation and prioritization of control applications respecting human exposure to potential pests or vector mosquitoes, they are intrinsically flawed. Unless conscious measures are taken, and complaint calls are properly logged, scheduled and acted upon, potential problems and shortcomings will arise. Additionally, citizens may give up and fail to call by deciding to hunker down and take it if the mosquito control agency customarily fails to act in their favor. Conversely, the proposed system does not depend on calls and can operate independently of them if necessary.

Exceptions to This Decision Rule Action Threshold Model

Label limitations, which include retreatment restrictions and waiting periods designed to limit over-dosage per acre. Also, weather conditions or high winds may preclude applications for what would otherwise be normal treatments within the purview of this model. The existence of non-target species (ex: Miami Blue butterflies, etc.) as well as the presence of nearby shorelines, environmentally sensitive areas or mosquito resistance in some treatment areas may restrict normal decisions to treat if no other formulations are immediately available. Moreover, citizen no-spray requests can also limit local applications.

Concluding Remarks

If one examines the 74-page data presented in this action threshold model, it is my hope that the introduction of a simple, practical model that not only tracks mosquito species, but also considers human exposure to them may promote beneficial insights among my peers. Thus, the realization of the need for the adoption of more responsible environmental mosquito control applications may more frequently be considered in both public and private venues. It is the author's belief that this report can add credence and insight for practical mosquito control decision making.

Sources

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